

Appl. No. 09/832,530  
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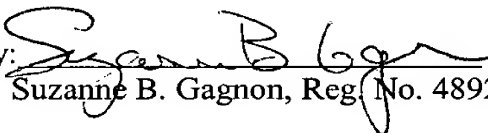
REMARKS/ARGUMENTS

The examiner has requested a substitute specification. The Applicant submits both a clean version and a marked up version of the substitute specification as required per 37CRF 1.125

If there are any additional fees resulting from this communication, please charge same to our Deposit Account No. 16-0820, our Order No. 33441.

Respectfully submitted,

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**Field of the invention**

1           The present invention relates to the field of ink-  
2           drop generators used in inkjet printers. It also relates  
3           to a print head and a printer using said ink-drop  
4           generator.

**Background art**

5           The principle of the inkjet printer is now well-  
6           known and has been described, for example, in the  
7           American patent No. US 3 373 437 granted to Richard G.  
8           Sweet. In this type of printer an ink-drop generator  
9           produces drops of ink that are electrically charged then  
10          deflected or not deflected by deflecting electrodes to  
11          print or not print a downstream substrate. The technology  
12          of deflected continuous jets has been widely used in  
13          industrial marking applications where inks incorporate  
14          volatile solvents and/or pigments for mediums that are  
15          difficult to mark where the atmosphere is rendered  
16          difficult due to the presence of dust and a variable  
17          temperature. The printed widths are small and the outputs  
18          are high. A generator of small drops, such as that  
19          described in French patent No. FR 2 653 063 (granted to  
20

1       the present applicant), generally comprises a single  
2       inkjet created from a pressurized inkjet cavity that has  
3       a jet nozzle on one of its surfaces.

4             The ink cavity also has an elongated cylindrical  
5       transducer on a surface opposite that which comprises the  
6       nozzle. Said transducer vibrates at a high frequency  
7       according to a longitudinal mode and constantly fragments  
8       the jet into regular, identical, equidistant droplets.  
9       The assembly consisting of the ink cavity, transducer and  
10      nozzle plate is called an ink-drop generator. The ink-  
11      drop generator is associated with charge electrodes,  
12      deflecting electrodes and possibly an ink collector to  
13      constitute a print head. One or more print heads can be  
14      mounted on the same printer. One or more ink-drop  
15      generators can also be assembled to constitute a single  
16      print head. For instance, patent application No. 2 653  
17      063 referred to above discloses a print head comprising  
18      at least two modulation bodies and therefore at least two  
19      nozzles equipped with means for adjusting each jet and a  
20      single ink-collector module with a single pipe for  
21      returning the ink to the common circuit. This type of  
22      print head offers the possibility of printing large  
23      characters at a higher rate than that provided by a head

1       with only one jet. The detailed embodiment of the  
2       invention described below also comprises two modulation  
3       bodies, which are also called acoustic-wave generators,  
4       shakers, resonators or transducers in documents  
5       concerning this technology, but each body actuates  
6       several inkjets.

7               In the description of the prior art contained in  
8       European patent EP 0 449 929 B1 it is recalled in col. 1,  
9       lines 24-25 and 54-58 that, for chambers comprising  
10      several jets, each nozzle is positioned facing either its  
11      own acoustic vibration generator or a section of a  
12      longitudinal acoustic generator whose measurements extend  
13      parallel to the line formed by the jet-nozzle assembly.  
14      The acoustic generator is supplied with sufficient power  
15      to print a vibration with ink in a direction parallel to  
16      the jet. The patent then points out in col. 2, lines 1-8  
17      that this configuration of the vibration generator  
18      relative to the nozzle plate is not indispensable  
19      provided certain conditions of resonance are met. If the  
20      conditions of resonance are complied with a single  
21      acoustic generator can stimulate the ink passing through  
22      a line of nozzles or part of a line of nozzles that has a  
23      length considerably greater parallel to the line of

1        nozzles than the size of the acoustic generator in the  
2        same direction, for example 5 to 10 times larger. The  
3        condition to be complied with is that the vibrating body  
4        vibrates virtually only in a longitudinal mode and at a  
5        resonance frequency that differs by -10% of the  
6        excitation frequency of the natural resonance vibrations  
7        in the ink of the cavity between the end of the body and  
8        the nozzle plate, the width of the body being smaller  
9        than the length of the series of nozzles or the part of  
10       the series of nozzles associated with said body.

11            In this patent the lateral walls of the ink chamber  
12        have a cross-section perpendicular to the line of nozzles  
13        disposed in a V shape. The tip of the V is turned towards  
14        the line of nozzles. The section of chamber comprising  
15        the V-shaped walls may be changed to enable the height of  
16        the V to be varied depending on the density of the ink  
17        and therefore the speed of the sound in the ink used.

18            Patent application WO 98 51503 also describes an  
19        ink-drop generator for an inkjet printer with the  
20        following characteristics: the lateral walls of a cavity  
21        containing the ink consist of interior and exterior  
22        walls. The resistance component of the acoustic impedance  
23        of the external walls is such that the external walls

1        passively dampen the vibrations of the interior walls by  
2        dispersing the vibrations. The reactive component of the  
3        acoustic impedance of the external walls is such that the  
4        external walls actively inhibit the vibrations of the  
5        internal walls, said external walls thus ensuring that  
6        each inkjet sprays drops of ink at the same predetermined  
7        distance from each respective nozzle. This type of  
8        configuration is used to prevent the nozzle bearing plate  
9        from bending in a direction parallel to the inkjet when  
10       the printer is used.

11       The present applicant has filed European patent  
12       application EP 0 532 406 A1 concerning multijet modules  
13       and the juxtaposition of several modules positioned side-  
14       by-side to obtain a large printing width. Much of the  
15       detailed description of the embodiment given below  
16       repeats the description of the above-mentioned  
17       application, particularly everything that relates to the  
18       mechanical fastening of print modules to a module  
19       assembly beam.

20  
21                    Brief description of the invention

22       As in the examples of embodiments in European patent  
23       applications EP 449 929 B1 or EP 0 532 406 A1 referred to

1       above, the invention relates to a multijet print head,  
2       i.e. a head in which a cavity containing pressurized ink  
3       delivers several jets that are divided into drops by a  
4       single resonator for said cavity. As in the embodiment  
5       described in European patent application EP 0 532 406 A1,  
6       the invention also relates to a print head capable of  
7       being mounted such that it is aligned with other heads to  
8       constitute a print assembly comprising a large number of  
9       jets equidistant from one another capable of  
10      simultaneously printing a wide band, for example two or  
11      more metres.

12       The multijet cavities of the prior art described,  
13      for example, in patent applications WO 98/51503 or EP 0  
14      449 929 B1 referred to above, enable a single resonator  
15      to actuate several jets. However, the end jets, i.e.  
16      those leaving the first and last nozzles of the cavity,  
17      spray irregularly, produce distorted drops or are formed  
18      at variable distances when said end jets are too close to  
19      the walls of the cavity.

20       The inventor of the present invention has used  
21      digital simulations to improve the quality of the end  
22      jets, for example by using a particular contour of the  
23      lateral wall at the nozzle plate, i.e. where said lateral

1 wall is secant to the nozzle plate. Another factor that  
2 affects the quality of the end jets is the angle formed  
3 by the lateral wall of the cavity with the nozzle plate.  
4 The angle is preferably  $90^\circ$  along the entire contour of  
5 the lateral wall.

6 The relation between the vibrating surface of the  
7 resonator and the surface of the nozzle plate should also  
8 be taken into consideration. The relation between the  
9 surfaces should preferably be approximately 1, for  
10 example between  $3/4$  and  $4/3$ . The shape of the  
11 transitional surface between a resonator housing and the  
12 cavity also plays a role. Finally, the relation of the  
13 cavity measurements is also important. Each of the  
14 factors mentioned above provides an improvement and the  
15 combination of all or some of the factors enables the  
16 spray quality of the end jets to be indistinguishable  
17 from the quality obtained with the central jets.

18 It becomes possible to position the end-nozzles very  
19 close to the intersection of the lateral wall of the  
20 cavity with the axial line joining the nozzles. Under  
21 these conditions, even though the distance between  
22 consecutive nozzles may be small, it remains possible to  
23 create an alignment of several cavities in which all the



1        nozzles are equidistant despite the thickness of the wall  
2        separating two consecutive cavities of the same head or  
3        two consecutive print heads.

4                Compared to known embodiments, the present invention  
5        also relates to an ink-drop generator suitable for a wide  
6        range of inks that does not require the drop generators  
7        to be modified and that can be produced in materials  
8        capable of withstanding temperatures to which print heads  
9        may be exposed in an industrial environment.

10               To achieve all these aims, the invention relates to  
11        an ink-drop generator for an inkjet printer in which an  
12        inkjet is sprayed in drops, said generator particularly  
13        comprising:

- 14               - a generator body,
- 15               - at least one acoustic wave generator with a body  
16        elongated in an axial direction to the inkjets, each  
17        generator having a vibrating surface perpendicular to the  
18        axial direction of the jets, at least one section  
19        comprising the vibrating surface of each acoustic  
20        generator being housed in a housing of the drop-generator  
21        body,
- 22               - at least one resonance cavity intended to contain  
23        ink, the first section only of each cavity possibly being

1        constituted in a main section of said body constituting  
2        the main body of the generator and, in this  
3        configuration, a second section in a continuation of said  
4        main body of the generator connected to be leaktight to  
5        the main body of the generator, each cavity having an ink  
6        feed and an ink-feed aperture, each cavity being  
7        particularly defined by a nozzle plate and a lateral wall  
8        secant to the nozzle plate, the intersection of the  
9        lateral wall and the nozzle plate defining a first  
10       contour line of the lateral wall, the nozzle plate  
11       comprising a plurality of nozzles aligned along an axial  
12       direction of the nozzles perpendicular to the axial  
13       direction of the jets, the axial direction of the jets  
14       and the axial line of the nozzles defining a plane of the  
15       jets,

16       - a generator characterized in that the lateral wall  
17       of each resonance cavity is secant to the nozzle plate  
18       perpendicular to said nozzle plate along the entire first  
19       contour line of said wall, the first contour line being  
20       formed by two equal segments that are parallel to one  
21       another and the axial direction of the nozzles, each  
22       segment having two ends: a first and a second end, the  
23       two first ends of each segment being connected by a first

1 curved line and the two second ends of each segment being  
2 connected by a second curved line.

3 The lateral surface of the cavity therefore consists  
4 of two plane walls parallel to one another and, at the  
5 axial line of the nozzles, one of the walls containing  
6 one of the segments and the other, the other segment, and  
7 two curved connecting walls each containing one of the  
8 contour curves.

9 In one embodiment the connecting curved lines of the  
10 segment ends are concave towards the inside of the  
11 cavity. In general, in order to facilitate manufacture  
12 the curved lines are constituted by semicircles the  
13 diameter of which is the space between the two segments.  
14 Preferably, in order to facilitate a preferred vibration  
15 mode in the fluid the largest measurement  $l$  of the first  
16 contour of the cavity lies along the axial line of the  
17 nozzles, the distance between the two segments is  
18 approximately  $l/4$  and the height of the lateral wall of  
19 the cavity is between  $l/2$  and  $3l/4$ , preferably  
20 approximately  $5l/8$ . To enable the vibrations produced by  
21 the acoustic-wave generator to be transmitted to the ink  
22 contained in the cavity it is necessary to connect the  
23 acoustic-wave generator housing to the cavity. The

1 connection is achieved by a hollow connector section  
2 defined by a lateral connector surface. Said connector  
3 surface is intended to connect, for example, a  
4 cylindrical shape with a circular base, the diameter of  
5 which is the diameter of the acoustic-wave generator, to  
6 a cylindrical shape with a more or less flattened  
7 rectangular base that is the shape of the lateral surface  
8 of the ink cavity. As described above, the space between  
9 the two walls of the largest surfaces of the cavity is  
10 preferably equal to  $1/4$ . The connector surface is  
11 preferably obtained as follows: to create the first  
12 section of the surface the cylindrical surface with a  
13 circular base, the diameter of which is between  $1/2$  and  
14  $3 1/4$  of the acoustic-wave generator, is extended over the  
15 section of its periphery that lies between the two planes  
16 defined by the largest plane walls of the cavity  
17 separated by a distance of  $1/4$ .

18 Each of the largest walls and/or a continuation of  
19 each wall is also hollowed to obtain a hollow the  
20 periphery of which is defined by a curved line in the  
21 plane of said wall and part of a circle the diameter of  
22 which is equal to the diameter of the acoustic-wave

1 generator, said circle being located in a plane  
2 perpendicular to the plane wall of the cavity.

3 The base of the hollow section, which is defined as  
4 described above, may be a conical surface, for example,  
5 to obtain a progressive junction between the generator  
6 housing and the resonance cavity. This junction forms an  
7 opening with a more or less rectangular cross-section  
8 between the resonator housing and the resonance cavity.  
9 The junction of the walls between the resonator housing  
10 and the cavity is achieved progressively.

#### Brief description of the drawings

11 An example of an embodiment of the invention will  
12 now be described with reference to the attached drawings  
13 where:

14 - figure 1 is an exploded perspective view of an  
15 example of an embodiment of the mechanical parts of a  
16 print head, the said parts comprising in particular the  
17 ink-drop generator body and an ink distributor /  
18 collector;

19 - figure 2 is a longitudinal cross-section along the  
20 plane of the ink-drop generator body and its  
21 continuation;

1           - figure 3 is a section through the assembled body  
2           with its continuation in a plane perpendicular to that of  
3           the jets and parallel to the nozzle plate;

4           - figure 4 is a transverse cross-section along a  
5           plane perpendicular to that of the jets and that of the  
6           nozzle plate of the ink-drop generator body and its  
7           continuation;

8           - figures 5 are in three parts, A, B and C; these  
9           three parts of the figure show the shapes of the contours  
10          of the intersection of the connection surface between the  
11          housing of the sound wave generator and the cavity, the  
12          said sections being along planes parallel to the nozzle  
13          plate;

14          - figure 6 is a cross-section through the generator  
15          body along line E-E of figure 2;

16          - figure 7 shows a perspective view of part of a  
17          printer comprising an alignment of print heads comprising  
18          ink-drop generators of the invention;

19          - figures 8 and 9 show schematic views of cross-  
20          section of the part located behind a multijet print  
21          module fitted on a supporting beam of a plurality of  
22          modules;

1           - figure 8 particularly shows a detailed view of the  
2     ink feeding pipes;

3           - figure 9 particularly shows a detailed view of the  
4     ink drainage and recovery pipes;

5           - figure 10 shows part of a printer designed to show  
6     the shape of the feeding pipes of the various ink  
7     generators;

8           - figure 11 shows part of a printer comprising  
9     several alignments of print heads arranged in series.

10          Figure 1 is an exploded perspective view of an  
11     assembly of mechanical parts composing part of an ink-  
12     drop generator 33 of the invention. It will be seen below  
13     that the generator 33 comprises a body 133, an ink  
14     distributor / collector 29 and an ink-drop deflection  
15     assembly 32. In the part discussed here relative to  
16     figure 1 the body 133 and distributor / collector 29 will  
17     be described.

18          Body 133 comprises a dual body 1 forming main body 1  
19     and a continuation 2. Dual body 1 comprises a section  
20     with two cavities 6. Each cavity 6 is partly composed of  
21     a hollow in dual body 1 and partly of a hollow in  
22     continuation 2 of dual body 1. Continuation 2 is  
23     connected to dual body 1 by means of a sealed connection.

1       The continuation 2 of dual body 1 is mechanically  
2       composed of a mechanical assembly of three parts, a  
3       housing 4 of a cavity part, a thin strip 3 bearing  
4       calibrated holes 36 forming nozzles and a reinforcement  
5       plate 5. The reinforcement plate 5 and strip 3 are  
6       fastened by means of a sealed connection, known per se,  
7       for example welding, to a base located outside housing 4  
8       of some of the cavities 6. Holes in part 5 and the base  
9       of part 4 allow jets of ink to pass from inside cavity 6  
10      through nozzles 36. This embodiment of the nozzle-plate,  
11      known per se, makes it possible very accurately to  
12      calibrate the nozzles, for example by laser-cutting thin  
13      strip 3 to form a clean, neat hole with a diameter of a  
14      few tens of  $\mu\text{m}$ . In the rest of the present text any  
15      reference to nozzle plate 39 is understood to refer to an  
16      assembly 39 comprising housing base 4, strip 3 and  
17      reinforcement 5.

18           Body 133 is divided into two sections, dual body 1  
19      forming the main body and continuation 2 of the body for  
20      machining purposes. The opening in body 133 allows  
21      machining of the upper section of cavities 6 using a bit  
22      that machines the bottom of dual body 1 and that in the



1 lower section of the same cavities via the top of  
2 continuation 2 of main body 1.

3 Other than the screws, the leaktightness,  
4 positioning and fastening means of main body 1 and its  
5 continuation 2 are shown in the drawings but not  
6 commented upon as they are known per se.

7 A description of a cavity 6 will now be given with  
8 reference to figures 2 and 3. Figure 2 is a cross-section  
9 along the plane of the jets of main body 1 and its  
10 continuation 2 mounted together. Figure 3 shows a cross-  
11 section through body 133 along plane C-C of figure 2  
12 close to the nozzle plate and parallel to the said nozzle  
13 plate.

14 A cavity 6 has the general shape of a rectangular  
15 parallelepiped of length 1, width more or less  $1/4$  and  
16 height somewhere between  $1/2$  and  $31/4$  but preferably  
17  $51/8$ . As explained above, these measurements are designed  
18 to encourage vibrations propagating along a plane wave  
19 parallel to nozzle plate 39. The shape of this cavity  
20 will now be explained in more detail with reference to  
21 figure 3. As stated above, this figure shows a section  
22 through a plane parallel to the nozzle plate located a  
23 very short distance from the nozzle plate. The contour of

1        this cavity consists of two planar segments 7, 8 that are  
2        generally parallel to one another and located at an  
3        approximate distance of  $1/4$  from one another. A side of  
4        each segment 7, 8 is illustrated in figure 3 as the trace  
5        in the cross-sectional plane of the parallel segments 7,  
6        8 that define an inner periphery of a portion of the  
7        cavity 6. Said segments 7, 8 are connected by arcuate  
8        planar portions 9, 10 a side of each arcuate planar  
9        portion 9,10 being illustrated in figure 3 as the trace  
10       in the cross-section plane of the arcuate planar portions  
11       9, 10. It will be seen from this drawing that cavity 6 is  
12       not altogether parallelepiped-shaped since a portion of  
13       its inner periphery includes arcuate formations causing  
14       the cavity 6 in this case to have the shape of half-  
15       cylinders with circular bases. As can be seen from figure  
16       2 or figure 4, which is a cross-section through body 133  
17       along line B-B, shown in figure 2, of a cavity, that also  
18       passes through the axis of a jet, arcuate planar portions  
19       9, 10 and segments 7, 8 of the cavity 6 are joined  
20       perpendicularly to nozzle plate 39. This shape makes it  
21       possible to avoid upward reflections of waves on the  
22       walls induced by the V-shaped form of these walls as  
23       described in the WO patent application cited above in the

1 description of the prior art. This shape therefore makes  
2 it possible to obtain more regular vibration of the ink  
3 in the cavity 6.

4 In each cavity the apertures 11, shown particularly  
5 in figure 2, provide the cavity with a supply of  
6 pressurized ink. The ink flows through the nozzles 36  
7 once the printer is operating. During jet startup,  
8 shutdown or maintenance, the ink may also be supplied in  
9 large quantities via aperture 12. This aperture has a  
10 cross-section greater than the sum of the cross-sections  
11 of the two ink-supply apertures 11.

12 The direction of the ink feeding pipes 11 is in the  
13 plane of the preferred vibration mode, perpendicular to  
14 the direction of the jets in order to minimise vibration  
15 disturbance. With the same end in mind they are also  
16 directed more or less along the smallest measurement  $1/4$   
17 of the cavity in order to minimise coupling with the main  
18 mode of interference vibration, which is that oriented  
19 along the largest measurement 1 of the cavity.

20 The two feed apertures 11 are located symmetrically  
21 relative to a central plane of cavity 6 perpendicular to  
22 the plane of the jets, and immediately below upper  
23 surfaces 107, 108 of the cavity. Ink outlet aperture 12

1 is located in a housing 13 of acoustic wave generator 14.  
2 The ink supplied via apertures 11 is intended to keep the  
3 cavity 6 filled and under pressure while the ink leaves  
4 via the nozzles 36. The ink outlet aperture 12 is used  
5 during startup, shutdown and hydraulic maintenance phases  
6 of the print head. The relative disposition and cross-  
7 sections of ink inlet aperture 11 and ink outlet aperture  
8 12 are optimized to ensure uniform distribution of the  
9 ink to the nozzles, so as to ensure that the ink in the  
10 cavity is not disturbed by the ink-flow pulsations coming  
11 from the ink circuit, to ensure that the ink in the  
12 cavity is replaced rapidly (draining), and to eliminate  
13 any air bubbles in the cavity by ensuring that there is a  
14 high flow-rate of liquid during hydraulic maintenance  
15 sequences. The body also contains housings 13 each  
16 provided for an acoustic wave generator 14 already known  
17 per se that has the basic shape of a cylinder 15 ending  
18 in a surface 16 that is parallel to the plane of the  
19 nozzles, said surface 16 constituting the vibrating  
20 surface of the acoustic wave generator 14. The section of  
21 the housing 13 of the acoustic wave generator 14 closest  
22 to the cavity has the shape of a cylinder 17.

1           In figures 2 and 4 the acoustic wave generator 14 is  
2       shown in dotted lines, firstly in a position close to its  
3       assembled position, and secondly once in its assembled  
4       position. In the assembled position the contour of the  
5       acoustic wave generator 14 is practically identical in  
6       figures 2 and 4 with that of the housing of the generator  
7       14. In the drawings, particularly figures 2 and 4, the  
8       housing of the acoustic wave generator 14 is located  
9       above cavity 6. This "above" position is in no way  
10      compulsory in practice. However, the terms "above" and  
11      "below" are used as a convenient spatial reference to  
12      describe the position of components relative to one  
13      another. In the example shown, the cylinder of the  
14      acoustic wave generator 14 is of diameter  $1/2$ , i.e. half  
15      the length of cavity 6 and its axis lies both in the  
16      plane of the jets and equidistant between the ends of  
17      cavity 6. In operation, the vibrating surface 16 of  
18      generator 14 is located level with the upper section of  
19      the cavity 6. This arrangement is in no way compulsory  
20      and this surface may be disposed slightly higher in the  
21      housing 13 of the acoustic wave generator 14. Given the  
22      shape of the acoustic chamber and the shape of the  
23      housing of generator 14, in order for the acoustic waves

1       to be transmitted efficiently and in a preferred  
2       vibration mode through the ink in cavity 6, it is  
3       necessary to provide a connection 18 between housing 13  
4       of acoustic wave generator 14 and cavity 6. This  
5       connection 18, which consists of a hollow in the segments  
6       7, 8, will now be described.

7             It should first be noted that in terms of the width  
8       of cavity 6 the connection is provided by the  
9       continuation of the cylindrical surface of housing 13 of  
10      acoustic wave generator 14. This point will be explained  
11      in greater detail below with reference to figure 5A.

12            Figure 5A shows the shape of the cross-section of  
13      cavity 6 as a plane parallel to the plate 39 carrying the  
14      nozzles 36. The projection on the cross-section plane of  
15      cylinder 17 forming the housing of acoustic wave  
16      generator 14 is also shown in dotted lines on a section  
17      outside cavity 6 and in unbroken lines inside cavity 6.  
18      The centre of the circle representing this projection is  
19      located on the longitudinal axial line of cavity 6  
20      equidistant between the two ends of this cavity. For the  
21      sections of the connection located between the two planar  
22      segments 7 and 8 of cavity 6 shown in figure 5A, the  
23      connection surface includes as shown in part A of

1 continuations 19 and 20, shown by unbroken lines, of the  
2 cylindrical section 17 of the housing 13 of acoustic wave  
3 generator 14. In this way, looking at connection 18 along  
4 an axial line of a jet, it will be seen to have a shape  
5 whose projection onto the cross-section plane shown in  
6 figure 5A will now be explained.

7 This opening is composed of a closed cylindrical  
8 surface comprising, on the one hand, continuations 19 and  
9 20 of the cylindrical surface and, on the other, the flat  
10 parts of the surfaces of the planes containing segments 7  
11 and 8 lying between the ends of said continuations 19 and  
12 20 of the cylinders. The shape of that section of the  
13 lateral surface of connection 18 that lies between  
14 connection 19 and 20 of the cylindrical surface will now  
15 be explained.

16 In order to define this shape, figure 5B shows a  
17 cross-section through the wall of connection 18 in a  
18 plane parallel to the nozzle plate located between a low  
19 end section and a high end section of connection 18. The  
20 cross-section of this connection consists of a line  
21 comprising, in order, an end of continuation 19, a  
22 straight section 22 that is part of segment 7, followed  
23 by a curved section 21, and finally another section 23 of

1 segment 7, an end of continuation 20 and sections 23',  
2 21', 22' that are respectively symmetrical with sections  
3 23, 21, 22 relative to a longitudinal axis XX' of the  
4 cavity. We will now consider the variations in the length  
5 of said curved section 21 between the low end section of  
6 the wall and the high end section. In the low end section  
7 of connection 18 the length of curved section 21, shown  
8 in part A of figure 5, is nil such that the perimeter of  
9 the section is composed of sections of continuations 19  
10 and 20, sections 22, 23 of segment 7 joining the ends of  
11 continuations 19 and 20 and sections 22', 23' of segment  
12 8 joining the ends of said continuations 19, 20. When the  
13 cross-section plane located between the low end sections  
14 and the high end sections approaches the high end section  
15 the measurements of sections 22, 23 located between  
16 curved section 21 and each of continuations 19, 20  
17 respectively diminish and the length of section 21  
18 increases. As the high end section as shown in part C of  
19 figure 5 is reached the length of sections 22 and 23 is  
20 nil and curve section 21 consists of a circular section  
21 forming a continuous arcuate portion extending between  
22 continuations 19 and 20.



1           Naturally if housing 13 and generator 14 were not  
2           circular cylinders but had a different shape, section 21  
3           at the top would have the shape resulting from an  
4           intersection of this shape with a plane parallel to the  
5           nozzle plate. In the example described the intersection  
6           of high end section of connection 18 with a plane  
7           parallel to nozzle plate 39 consists of a circular closed  
8           line whose diameter is equal to the diameter of housing  
9           13 of acoustic wave generator 14, for example  $1/2$ . The  
10          perimeter of this line is the perimeter of the circle.  
11          For an intermediary plane between the high end-section  
12          and the low end section the perimeter of the straight  
13          cross-section of connection 18 by a plane parallel to  
14          nozzle plate 39 is formed on the one hand by  
15          continuations 19, 20 of the circle, by sections 22, 23 of  
16          segment 7, by a curved section 21 by parts 22', 23' of  
17          segment 8 and by a curved section 21'. The perimeter of  
18          this intermediate cross-section is therefore smaller than  
19          the diameter of the circle located at the high end  
20          section. Similarly, coming to the low end part, the  
21          cross-section of connection 18 by a plane parallel to  
22          nozzle plate 39 has the shape shown in part A, i.e. two  
23          sections 19, 20 of a circle and two continuations of

1 segments 7 and 8 located between said two sections of  
2 continuations 19, 20. The perimeter of the low end part,  
3 shown in part A, is therefore smaller than the perimeter  
4 of the intermediate lower part shown in part B. Therefore  
5 the shape of connection 18 can be characterized by saying  
6 that the perimeter of its cross-section by a plane  
7 parallel to nozzle plate 39 reduces the further the plane  
8 of intersection is from the upper limit and approaches  
9 the lower limit.

10 It will also be noted that the ends of each of  
11 sections 21, 21' are located facing one another and thus  
12 separated from one another by a distance between segments  
13 7 and 8 of the first contour. In order for good plane  
14 propagation of the acoustic waves to occur, the walls of  
15 cavity 6 and connection 18 need to have rotational  
16 symmetry, i.e. symmetry relative to an axis or to two  
17 perpendicular planes passing through the said axis.

18 In one simple embodiment, part of connection 18 is  
19 made using a conical drill bit with an angle at its tip  
20 of, for example, 90°. When the bit is conical the  
21 different sections 21 are segments of circles of nil  
22 diameter at the lower end section and a diameter equal to  
23 that of housing 13 of the acoustic wave generator 14.

1        This embodiment is shown in figures 2 and 4. In figure 2  
2        the intersection of the cone with the plane of segment 7  
3        of the cavity results in a segment 24 of a hyperbola  
4        while figure 4, in which the cross-section is along  
5        section B-B, i.e. more or less along the axis of housing  
6        13 of acoustic wave generator 14, the intersection has  
7        the shape of two 90° segments 26. In this example,  
8        moreover, the low end section of housing 13 coincides  
9        with the high end section of cavity 6 and thus a low end  
10       section 25 of connection 18 is positioned at a distance  
11       from the top of cavity 6 slightly less than half the  
12       diameter of the cylindrical section of housing 13 of  
13       acoustic wave generator 14. Another important  
14       characteristic of the invention will now be explained. As  
15       was seen above, because the segments 7, 8 and arcuate  
16       planar portions 9, 10 of the cavity are perpendicular to  
17       the nozzle plate 39 at the level of said nozzle plate 39  
18       and that the section of connection 18 between the lower  
19       surface 16 of acoustic wave generator 14 and cavity 6 is  
20       created progressively, a plane wave perpendicular to the  
21       axis of housing 13 propagates in cavity 6. As this wave  
22       is plane, no problems are created due to boundary  
23       effects. Consequently a nozzle 361, 362 may be positioned

1       very close to one of arcuate planar portions 9, 10  
2       without its operation being affected. For example, it  
3       will be seen from figures 2 and 3 that an end-nozzle 361  
4       is located very close to the arcuate planar portion 10 of  
5       cavity 6. Similarly it will be seen that an end-nozzle  
6       362 is located very close to the arcuate planar portion 9  
7       separating two identical cavities of body 133. The  
8       closeness of nozzle 361 to the arcuate planar portion 10  
9       allows the axis of the nozzle to be at a distance less  
10      than half the interval between two consecutive nozzles of  
11      the cavity even if said interval is small. Similarly the  
12      distance between end-nozzle 362 of arcuate planar portion  
13      9 between two cavities 6 allows the distance between this  
14      nozzle 362 and the next consecutive nozzle located in the  
15      other cavity of body 133 to be less than the distance  
16      between two consecutive nozzles in a single cavity. Hence  
17      the interval between consecutive nozzles of all the  
18      nozzles in the two cavities remains equal, even when it  
19      is small. Moreover, due to the fact that the distance  
20      between one end-nozzle and the outer surface of the  
21      portion where it intersects with the axis of the nozzles  
22      is less than half the interval between two nozzles, it  
23      becomes possible to place side by side two modules that

1       are, for example, identical or have the same  
2       characteristic that the closeness of the nozzle of one  
3       cavity relative to the outer surface of the body  
4       containing said cavity, without the interval between two  
5       consecutive nozzles of the resulting assembly being  
6       modified.

7               To take the best advantage of this fact without the  
8       tolerances of an assembly of different bodies 133  
9       resulting from the accumulated effect of the measurement  
10      tolerances on each body, each body is fitted with  
11      positioning pins 124 that cooperate in a way known per se  
12      with positioning holes on a support beam 28 bearing the  
13      alignment of the bodies. Clearly the effect would be the  
14      same if the pins were on the alignment beam and the  
15      bodies fitted with positioning holes.

16             In the example explained here and shown particularly  
17      in figure 1, the positioning pins 124 are not fastened  
18      directly onto main body 1. Body 1 is fastened onto an ink  
19      distributor / collector 29. The distributor is an  
20      intermediate part used to connect body 133 to the ink  
21      circuit. For this purpose it has as many ink collection  
22      gutters 34 as there are nozzles and ink inlets and  
23      outlets known per se to maintain cavity 6 under pressure.

1 Part 29 is connected to body 133 by any fastening means  
2 and is positioned by positioning means, for example by  
3 continuations of the pins 124 fitting into the holes (not  
4 shown) in body 133.

5 It will be seen that in the embodiment described  
6 above the surface of nozzle plate 39 is  $\frac{l^2}{16}\left(3+\frac{\pi}{4}\right)$  and that  
7 the vibrating surface 16 of the resonator is  $\frac{\pi l^2}{16}$  such  
8 that the relation of the values of these two surfaces is  
9  $\left(\frac{3}{\pi}+\frac{1}{4}\right)$  or approximately 1.15.

10 The location of the ink inlet and outlet apertures  
11 will now be described with reference to figures 2 and 6.  
12 Figure 6 is a cross-section through dual body 1 at  
13 apertures 11 and 12 in a plane parallel to nozzle plate  
14 39:

15 As shown in figure 2, the ink inlet apertures 11 are  
16 each located at one end of cavity 6 more or less directly  
17 above end-nozzles 361, 362 respectively.

18 Since the diameter of the nozzles is very small  
19 (approximately  $50\mu\text{m}$ ), the rate of ink flowing through  
20 them is very slight. It follows that the ink-flow  
21 supplied to the nozzles is also very small. The cross-

1       section of ink inlet apertures 11 and ink outlet  
2       apertures 12 is set at a measurement considerably greater  
3       than the diameter of the nozzles such that the speed at  
4       which the ink still in the cavity travels is very slight.  
5       The ink is therefore subject to the vibrations of the  
6       transducer while it is virtually static.

7             The disposition of the ink inlet apertures 11 on the  
8       top ends of cavity 6 and immediately beneath upper  
9       surfaces 107, 108 respectively of cavity 6, which at this  
10      point mask the propagation of acoustic waves, limit the  
11      disturbance of vibrations by the ink-flow.

12            During maintenance operations the ink outlet occurs  
13      higher through an aperture 12 (shown in figure 2) located  
14      in the cylindrical section 15 of housing 13 of acoustic  
15      wave generator 14. The ink flows towards outlet aperture  
16      12 from cavity 6 through a clearance between the  
17      cylindrical section 15 and acoustic wave generator 14.  
18      The use of a single outlet aperture 12 eliminates areas  
19      of static fluid and optimizes drainage of the ink cavity.  
20      Finally, in normal operation the solenoid valves  
21      controlling the print head prevent ink from flowing  
22      through outlet aperture 12; the ink around this aperture

1 is therefore static. It also acts as a lubricant and  
2 vibration insulator for the acoustic wave generator 14.

3 Figure 6 shows ink pipes 37. The outermost sections  
4 of these pipes join curved surfaces 9, 10 such that they  
5 are tangential in order to optimise the drainage of the  
6 cavity. The two pipes 37 are symmetrical to one another  
7 relative to a perpendicular plane of the jet plane. They  
8 open into a distribution throat 88 located between dual  
9 body 1 and collector / distributor 29.

10 The assembly of generators or ink print modules 33  
11 that each comprise a body 133 and an ink collector is  
12 described below with reference to figures 7-9.

13 An example of this kind of module mounted on a beam  
14 28 is shown in figure 7. Figure 7 is a view showing a  
15 printing device comprising an assembly of eight print  
16 modules 140 of  $m = 8$  print jets 27 that form a continuous  
17 row of 64 regularly spaced print jets. The eight print  
18 modules are mounted adjacent to one another on a  
19 supporting beam 28 common to all the modules. Each print  
20 module comprises:

- 21 - a collector / distributor 29
- 22 - a multijet deflector assembly 32
- 23 - a body 133



1           - the collector / distributor, which is a one-piece  
2     body 29 comprising gutters 34 for collecting the non-  
3     deflected drops of each jet, supports body 133 which is  
4     capable of delivering 8 inkjets through 8 nozzles 36; the  
5     eight inkjets are regularly spaced in a plane parallel to  
6     beam 28;

7           - multijet deflector assembly 32 is shown in two  
8     positions: in the low, or working position on the modules  
9     located the furthest to the left of figure 7 and in the  
10    high, or maintenance position on the modules located the  
11    furthest to the right. The function of this type of  
12    deflector assembly and its construction are known in  
13    themselves. They will only therefore be described briefly  
14    below. When each jet of liquid leaves nozzles 36 it  
15    breaks up into micro droplets and passes through multijet  
16    deflector assembly 32 where certain drops are  
17    electrically charged by charge electrodes then deflected  
18    from their initial trajectory towards gutter 34 by  
19    deflecting electrodes, said deflecting and charge  
20    electrodes belonging to deflector assembly 32, to create  
21    an impact on a printing substrate that scrolls in front  
22    of the printing module. This type of multijet deflector  
23    assembly 32 to deflect  $m = 8$  inkjets is described, for

1        example, described in French patent application No. 91  
2        05475 filed by the present applicant on 3 May 1991.

3            An actuating part 31 that rotates multijet deflector  
4        assembly 32 around an axis 49 is constructed as part of  
5        supporting beam 28.

6            It will be seen in reference to figures 8 and 9 that  
7        the side of supporting beam 28 opposite that bearing  
8        collector 29 of each print module is associated with a  
9        single part 30 that creates, in combination with said  
10       beam 28, a tank 62 for collecting or draining the ink  
11       from the collector gutters of the eight print modules  
12       and, in combination with a single plate 110, a single  
13       cavity 111 for distributing the ink to the eight devices  
14       33 for generating the eight inkjets. Support beam 28 has  
15       internal pipes that connect, on the one hand, collector  
16       tank 62 and, on the other, gutters 34 of generator  
17       devices 33 mounted on supporting beam 28 and the internal  
18       supply pipes.

19            It should be noted that figures 8 and 9 are  
20        essentially schematic cross-sections to support the  
21        description and are not actual cross-sections of the  
22        device. It is for this reason that pipes in the figures  
23        are not always in the cross-section plane but in the

1 parallel planes. The schematic cross-section of figure 8  
2 is mainly of a plane of the feed pipes of a print module  
3 33 and a plane of ink-collector pipes undirected towards  
4 a printing substrate from gutters 34. The pipes used for  
5 ink collection are not necessarily in the same plane as  
6 those used for the supply.

7 Similarly, figure 9 mainly shows the plane of the  
8 ink drainage and collection pipes but the pipes relative  
9 to these two functions are not necessarily in the same  
10 plane.

11 As described above, body 133 is supplied with ink  
12 through pipes 37 pierced in body 133 and a collector  
13 throat 88 between body 133 and collector 29. Throat 88  
14 communicates with the rear of collector 29 via a hole  
15 pierced through said collector, as shown in figure 1 by  
16 an arrow. Similarly, drainage opening 12 communicates  
17 with the rear of collector 29 via pipes pierced in body  
18 133 and collector 29. Gutters 34 for collecting unused  
19 ink drops from a jet, i.e. non-deflected drops, provided  
20 in the lower section of collector 29 communicate with the  
21 rear section of collector 29 via an internal pipe of said  
22 collector 29. The eight internal pipes open into a  
23 suction cavity of collector 29.

1           Figures 8 and 9 show the workings at the rear of  
2           collector 29 in terms of the ink circuits.

3           The ink supply circuit of each print module will now  
4           be described with reference to figure 8. This figure is a  
5           schematic transversal cross-section through a supporting  
6           beam 28 of an assembly of modules and components on the  
7           rear section of said beam 28. A part 30 is assembled onto  
8           beam 28 by bolts and impervious seals (not shown). These  
9           bolts are also used to assemble a rear plate 110 to the  
10          rear of part 30.

11          Ink is distributed to all cavities 6 of the eight  
12          modules by a pressurized distributor 111 created on the  
13          rear surface of part 110. The distributor communicates  
14          with pipes 38 pierced through beam 28 via pipes that are  
15          preferably rigid, such as pipe 144 shown in figure 8 and  
16          solenoid valves 86 called feeding valves. In figure 8 a  
17          single connector pipe 144 between distributor 111 and a  
18          single solenoid valve 86 are shown. In fact there are as  
19          many pipes, solenoid valves 86 and pipes 38 as print  
20          modules.

21          Pressurized cavity 111 communicates with ink  
22          pressurizing means (not shown) via a connector 69.

1           A tank 62, shown in figures 8 and 9, is created by a  
2           first cavity provided in beam 28 and a second cavity  
3           provided in part 30. The collection and drainage circuit  
4           will now be described with reference to figure 9.

5           Tank 62, called the collector or drainage tank, is  
6           connected to a solenoid valve 89, called a drainage  
7           valve, via a pipe 63 of part 30, a throat 64 between  
8           parts 30 and 110, a pipe 65 pierced in part 110, an  
9           external pipe 120, a pipe 92 of part 30, a throat 91  
10          between parts 30 and 110 and a pipe 90 pierced in part  
11          30. Said solenoid valve 89 is also connected to the rear  
12          of collector 29 by a pipe 77. Said pipe 77 communicates  
13          with opening 12 of cavity 6 through collector 29 and body  
14          133. Tank 62 is common to all the print modules mounted  
15          on beam 28, i.e. the eight modules shown in figure 7.  
16          There is a pipe 77, 90, 65, 63, a throat 91, 92 and a  
17          drainage solenoid valve 89 for each print module. Tank 62  
18          also communicates with the collector gutters of  
19          collectors 29 via pipes 59 pierced in beam 28. The single  
20          tank 62 communicates with a suction pump (not shown) via  
21          a single 73 pipe pierced through parts 30 and 110.

22          During printing the non-deflected ink from gutters  
23          34 is permanently sucked and returned to the ink circuit.

1 In the drainage mode solenoid valves 89 are open and the  
2 suction pump sucks ink from tank 62 collected from the  
3 gutters and openings 12 of cavities 6.

4 Another aspect of the invention will now be  
5 described with reference to figure 10 that shows a rear  
6 perspective view of a supporting beam 28. As explained  
7 above the rear surface of support 28 is associated with a  
8 single part 30 that creates, in combination with said  
9 beam 28, a collector or drainage tank 62 (figures 8, 9)  
10 and, in combination with a plate 110, a cavity 111 for  
11 distributing ink to the eight devices 33 for distributing  
12 eight inkjets.

13 The aim of figure 10 is to show a characteristic of  
14 pipes 141-144 that each supply an ink generator 33.

15 The aim of this characteristic is to ensure that the  
16 pressure drops are identical in each pipe 141-144 joining  
17 distribution cavity 111 to each generator 33,  
18 irrespective of the position of the generator relative to  
19 cavity 111.

20 To this end all pipes 141-144 are of the same  
21 length.

1           Moreover, all the pipes include the same number of  
2           elbows. The value of an elbow angle of a pipe is  
3           identical on all the other pipes.

4           These characteristics of pipes will now be described  
5           in detail in reference to figure 10. As this figure is a  
6           semi-cross-section, only four pipes are visible. A pipe  
7           that supplies four other pipes symmetrical to pipes 141-  
8           144 relative to a plan perpendicular to beam 28 is not  
9           shown.

10           Each connector pipe has a start end section 141a-  
11           144a perpendicular to plate 110 and a finish end section  
12           141b -144b also perpendicular to plate 110. The end  
13           sections of a pipe, for example 144a, 144b, are connected  
14           together by a central pipe section 144c parallel to plate  
15           110. The length of this section varies depending on the  
16           distance between the supply point of a generator 33 and  
17           the starting point of cavity 111. The sums of the lengths  
18           of sections a, b, c of each pipe 141-144 are equal. This  
19           means, for example, that central section 141c of pipe 141  
20           that supplies a generator 33 close to central supply  
21           cavity 111 is shorter than central section 144c of pipe  
22           144 that supplies a generator 33 further away from cavity  
23           111. On the other hand end sections 141a, 141b of pipe

1        141 are longer than sections 144a, 144b of pipe 144.  
2        Given the different configurations pipes 141-144 are  
3        nevertheless equal in length. They each comprise two  
4        connector elbows that are at right angles and with the  
5        same radius of curvature. All the pipes are rigid, for  
6        example metal, to enable them to retain their shape. In  
7        the example of figure 10 it was not necessary to include  
8        a section of S-shaped piping to absorb the dilations  
9        although one could be provided depending on the  
10       conditions of use of the printer assemblies. The position  
11       of the S-shaped sections in the piping matters little, it  
12       being essential however that they are identically shaped  
13       and connected to the rest of the piping.

14       A printer of the invention comprises one or more  
15       supporting beams 28 equipped with print heads 32 that  
16       enable ink to be sprayed towards a printing substrate. In  
17       principle when there are several beams each beam prints a  
18       different colour ink such that a colour image is  
19       produced. The advantage of a printer configured according  
20       to the invention is that an entire width of the substrate  
21       may be printed simultaneously. Under these conditions a  
22       relative movement of the print heads and the substrate in  
23       a parallel direction to beam 28 is no longer necessary



1        because the width that is printed simultaneously can be  
2        adapted to the width of the substrate. The only remaining  
3        movement is that of the head relative to the substrate in  
4        a direction perpendicular to support beam 28. This may be  
5        a continuous, rapid movement.

6                Figure 11 shows a printer provided with several  
7        support beam assemblies 28 positioned parallel to one  
8        another and printing the same substrate scrolling  
9        perpendicular to the beams. Figure 11 is a schematic  
10       perspective view of this type of configuration. A support  
11       frame 150 holds a set of beam assemblies 28a, 28b, 28c.

12               Means (not shown) enable substrate 151 to scroll  
13       under the inkjets of print modules or heads 14a of beam  
14       28a, then 140b of beam 28b and 140c of beam 28c.

15               The beam 28a the furthest upstream relative to the  
16       scrolling substrate periodically prints a reset mark, for  
17       example on an edge of the substrate. Each downstream beam  
18       28b, 28c is provided with a position sensor (not shown)  
19       to detect these marks and enable the pixel data of the  
20       line to be reset virtually continuously. Good  
21       superimposition of colours is therefore obtained.